

## 6. HIGHLIGHTS OF LABORATORY FOR ATMOSPHERES ACTIVITIES IN 2001

In this section, you'll learn about some of the Laboratory's research accomplishments for 2001. We have divided this material into two groups. First, you'll see a branch-by-branch summary of highlights. Then, you'll see short articles presenting the results of specific science research highlights. The Branch Web sites can be accessed from the Laboratory for Atmospheres Web site at <http://atmospheres.gsfc.nasa.gov/>.

### Summary of Branch Highlights

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#### ***Data Assimilation Office (DAO), Code 910.3***

The Data Assimilation Office (DAO) works to advance the state of the art of data assimilation. The DAO's objectives are:

- To produce research-quality assimilated data sets for addressing questions in studies of the Earth system and of global change.
- To make the best use of satellite data for climate assessment.
- To assist Earth Observing System science and instrument teams.

The DAO's accomplishments in 2001 include these—

- 1) We released the first version of DAO's next-generation data assimilation system. This system is based on a state-of-the-art general circulation model. The model consists of the finite-volume dynamical core developed at DAO, coupled to physical parameterizations from NCAR. This "finite-volume" data assimilation system (fvDAS) employs an adaptive statistical quality control, which examines the quality of the input data stream taking in consideration the "flow of the day." The system ingests data from a variety of conventional and remotely sensed data, including rawinsondes, TOVS Level 1B radiances, and scatterometers. The core assimilation algorithm is DAO's Physical-space Statistical Analysis System (PSAS), a global 3-D VAR class solver that combines model short-term forecast with observations to provide an optimal estimate of the atmospheric state. Compared to the GEOS-3.2 operational system, the fvDAS has better forecasts skills, an improved stratospheric circulation, more realistic representations of synoptic systems, and a faster throughput. The fvDAS is scheduled to replace GEOS-3 as DAO's real-time operational system in the first half of 2002.
- 2) The GEOS-3 operational system provided daily first-look and late-look data products to EOS Instrument Teams without serious production anomalies. The operational system was upgraded throughout 2001, including a smooth transition from RTOVS to ATOVS data in the operational input data stream. During TRACE-P and ACE-Asia chemistry missions, the DAO provided near real-time direct support to the science teams with customized assimilated data products, which received appreciative commendations from the mission scientists. The DAO also delivered to ECS data products that were created by reprocessing data of October to December 2000 using the latest operational system in support of MODIS data processing.

- 3) We conducted advanced data assimilation research in the use, retrieval, and full exploitation of remotely sensed data. In 2001, DAO scientists developed a 1D-variational scheme that simultaneously performs cloud clearing and retrieves information about temperature, humidity, ozone, and surface parameters including the surface skin temperature from TOVS. The implementation of this procedure in the fvDAS resulted in improved 5-day forecasts and in smaller biases and standard deviation errors in 6-hr forecast winds and heights verified against radiosonde data.

### ***Mesoscale Atmospheric Processes Branch, Code 912***

The Mesoscale Atmospheric Processes Branch seeks to understand the contributions of mesoscale atmospheric processes to the global climate system. We conduct research on the physical and dynamical properties, structure, and evolution of meteorological phenomena, with a strong focus on the initiation, development, and effects of cloud systems. We investigate phenomena on a wide range of scales, from the synoptic scale to the microscale. A major emphasis is on energy exchange and conversion mechanisms, especially cloud microphysical development and latent heat release associated with atmospheric motions. The work is inherently focused on defining the atmospheric component of the global hydrologic cycle, especially precipitation, and its interaction with other components of the Earth system. Branch activities include satellite missions, advanced remote sensing technology development and application, modeling and analysis, and visualization.

- 1) Branch scientists retrieve precipitation estimates using satellite and ground observations. Satellite data comes from the Tropical Rainfall Measurement Mission (TRMM) and from earlier and continuing SSM/I and GOES observations. Ground-based data comes from rain-gauge networks and from radar. Branch scientists are engaged in all phases of field work to support validation of satellite-derived precipitation estimates, including application of an airborne (NASA ER-2) Doppler precipitation radar (EDOP). The Branch is also strongly engaged in future missions such as the AMSR-E on EOS Aqua, to be launched in 2002, and the developing Global Precipitation Mission (GPM). A major effort has been made to characterize the rainfall data products generated by different instruments on the TRMM satellite. This analysis is a key step toward a best estimate of precipitation climatology. Major accomplishments include—

- Extending the lifetime of TRMM through an orbit boost.
- Actively participating in the CAMEX-4 field campaign in August–September 2001 to study hurricanes.
- Developing a near real-time global-tropics 3-hourly rainfall analysis based on data from multiple satellites and sensors.
- Studying the effects of deforestation on rainfall distribution over the Amazon.
- Studying El Niño and other climate systems.
- Helping move the GPM mission into the formulation phase.

- 2) Branch members are engaged in research and development of lidar technology. The technology will enable us to characterize the profile structure of cloud systems (Cloud Physics Lidar–CPL), atmospheric aerosols (Micro Pulse Lidar–MPL), water vapor (Scanning Raman Lidar–

SRL), and winds (Goddard Lidar Observatory for Winds–GLOW) at fine temporal and/or spatial resolution. We can gather these lidar observations from airborne and satellite platforms and from ground-based systems. Of particular note are capabilities to characterize atmospheric structure in the planetary boundary layer and in high-level cirrus clouds, and support of NASA's planned Global Tropospheric Winds mission. In addition, the Cloud Radar System (CRS), a new millimeter-wavelength *radar* for profiling cloud systems, has been developed and will soon be integrated on NASA's high-altitude ER-2 research aircraft for use in sensing the microphysical properties of cirrus and other cloud types.

Branch scientists play a key role in developing the atmosphere-sensing capabilities of the Geoscience Laser Altimeter System (GLAS). GLAS will be launched on ICESat in late 2002. Major accomplishments include assembling, aligning, and testing the optics and detector hardware; and delivering and testing the at-launch algorithms for GLAS atmospheric data products, including aerosol and cloud profiling. Branch scientists also serve as Project Scientists for the Earth System Science Pathfinder (ESSP), CALIPSO (lidar), and CloudSat (mm-radar) missions that are planned for launch in 2004.

Another major accomplishment was the graduation to operational status of the MPL-Net project, with eight operational sites/systems. MPL-Net is a Goddard-based federation of lidar sites sharing a common data processing (algorithms), archive, and access system. The federation includes three sites of the Department of Energy Atmospheric Radiation Measurement (ARM) Program and two sites operated by Japan. GSFC maintains sites at the South Pole and at Goddard. GSFC also maintains systems used in field experiments, including ocean research cruises such as the Aerosol Characterization Experiment (ACE–Asia) in the spring of 2001. MPL-Net data products are now documented and routinely available to the community via the MPL-Net Web site (<http://virl.gsfc.nasa.gov/mpl-net/>). MPL observations have proven very useful for modeling GLAS algorithm performance and accuracy.

- 3) The mesoscale (MM5) and cloud-resolving Goddard Cumulus Ensemble (GCE) models are used in investigations of the dynamic and thermodynamic processes associated with numerous weather and climate phenomena. These include cyclones and frontal rainbands, tropical and mid-latitude deep convective systems, ocean-surface and land-surface (vegetation and soil moisture) effects on atmospheric convection and weather systems, cloud-chemistry interactions, and stratospheric-tropospheric interaction. Other important applications of the MM5 and GCE models include assessment of the potential benefits of assimilating satellite-derived water vapor and precipitation fields on tropical and extra-tropical regional-scale (i.e., hurricane and cyclone) weather simulations. Long-term integration of the models will allow study of air-sea and cloud-radiation interactions and their role in cloud-radiation climate feedback mechanisms. The simulations provide a basis for integrated systemwide assessment of important factors such as surface energy and radiative exchange processes, and diabatic heating and water budgets associated with tropical and mid-latitude weather systems. The models are also used to develop retrieval algorithms. For example, the GCE model is providing TRMM investigators with 4-dimensional data sets for developing and improving TRMM rainfall and latent heating retrieval algorithms.

The scientific output of the modeling activities was prodigious in 2001. We submitted nearly 20 papers for publication, and most have already been accepted. A major accomplishment was the publication of the first extensive analysis of vertical profiles of latent heating produced from TRMM data using model-derived algorithms. Another significant result was the identification and description of a dynamical instability leading to a secondary circulation that plays a key role in hurricane intensification. This work indicates that the hot towers concept is a viable description of eye wall convection and that explanations based on slant convection or broad ascent are not required. In the hot towers analysis, upward motion is concentrated in a small number of intense isolated thunderstorm updrafts.

Branch scientists actively participate in or lead various international model comparison and evaluation activities of the GEWEX Cloud System Study. These activities aim to increase confidence in these tools and facilitate research on the development and testing of cloud parameterizations used in large-scale climate and forecast models (GCMs). Of particular note is a model comparison study of microphysical development in cirrus clouds that identifies key parameters, such as deposition coefficient, to which the models are highly sensitive and for which additional information is required (e.g., laboratory studies).

- 4) The Branch has developed a world-class visualization lab that is being increasingly used in high-profile settings to reach out to scientists and, very importantly, to citizens and government organizations to stimulate understanding and support of NASA's Earth Science Enterprise and its missions. These capabilities are heavily utilized by the TRMM Outreach Office, Earth Observing System (EOS) Project Science Office, and NASA HQ in bringing the value of TRMM and EOS science to the forefront of U.S. global change research.

#### ***Climate and Radiation Branch, Code 913***

The Climate and Radiation Branch conducts research to improve understanding of climate processes and their societal impacts, using space-based as well as in situ observations and modeling. Research focuses on physical processes underlying the formation of aerosols, clouds, and precipitation, and their interaction with atmospheric dynamics and radiation.

The Branch's accomplishments in 2001 include the following:

##### **1) Clouds, precipitation and the water cycle—**

We discovered from satellite data a fundamental relationship between clouds, water vapor and sea surface temperature (SST), with a new interpretation on cloud water vapor-climate feedback processes.

We developed an improved rain retrieval method based on spatial structures of the TRMM microwave radiometer (TMI) observations. The method will provide better discrimination of convective and stratiform precipitation.

We developed a simple method of estimating mean squared random error in monthly rainfall estimates, based on quantities that can be directly computed from the satellite data. This method will have potential application in the design of the Global Precipitation Mission (GPM).

##### **2) Aerosol climate interactions—**

MODIS data collaborated previous findings with Landsat and AERONET that dust absorption of solar radiation is much smaller than previously estimated, implying possibly a stronger global cooling effect by desert dust.

The ACE–Asia campaign showed global transport of dusts and aerosols from central Asia to North America with possible climatic, ecological, and human impacts.

We demonstrated for the first time the feasibility of using a combination of aerosol measurements from MODIS and MISR, carbon monoxide measurements from MOPITT, and energy measurements from CERES to distinguish man-made combustion aerosol from natural aerosol.

We provided value-added capability to the Terra data system to allow the Forest Service to use MODIS images for monitoring the wildfires of the western U.S. during the dry seasons. This use of Terra data permitted unprecedented near real-time (within 15 hours) observations of fires, smoke, and the spread of pollution.

### 3) Climate variability and predictability—

We discovered a climate teleconnection pattern linking U.S. summertime severe droughts and floods to monsoon heat sources and sinks around the world.

We developed a canonical ensemble prediction system to identify new sources of potential predictability for U.S. seasonal precipitation, raising the skill bar for seasonal prediction.

We provided basic understanding and a new interpretation of monsoon and its interaction with the ITCZ.

We developed a new generation catchment-based land-surface model for use in climate studies, and carried out experimental dynamical seasonal predictions with a state-of-the-art production version of the NSIPP atmospheric GCM.

We developed a new parameterization for snow cover that includes separate predictions of the temperatures of snow and the ground underneath. These improvements have led to better climate simulations in atmospheric general circulation models.

We demonstrated that remote forcing from radiative cooling in the subsidence region exerts strong control on the cloudiness distribution in the warm pool region, and that the gradient of SST likely plays an important role in controlling cloud radiative feedback associated with global warming.

We organized 3-D radiation intercomparisons showing large plane parallel and IPA bias in radiation codes in climate models.

### 4) Technology development—

We developed versatile, mobile platforms to measure surface and atmospheric radiation, water vapor and aerosols (3S photometers, SMART, Leonardo airborne simulator) for deployment in major international field campaigns.

We fabricated a laboratory instrument, the THOR lidar, which is designed to measure cloud thickness from off-beam lidar returns. The instrument is being prepared for airborne deployment and for competitive award under the Instrument Incubator Program (IIP).

### 5) Advanced concepts and new visions—

We championed and submitted a proposal to NASA Headquarters for establishing a Center of Excellence for Aerosol Climate Research within the Laboratory, and lead the Directorate-wide Aerosol crosscutting team development.

We developed an advanced concept for AEROSAT— an aerosol satellite to include aerosol polarization and black carbon measurements to unravel and reduce uncertainties on effects of aerosols on global change.

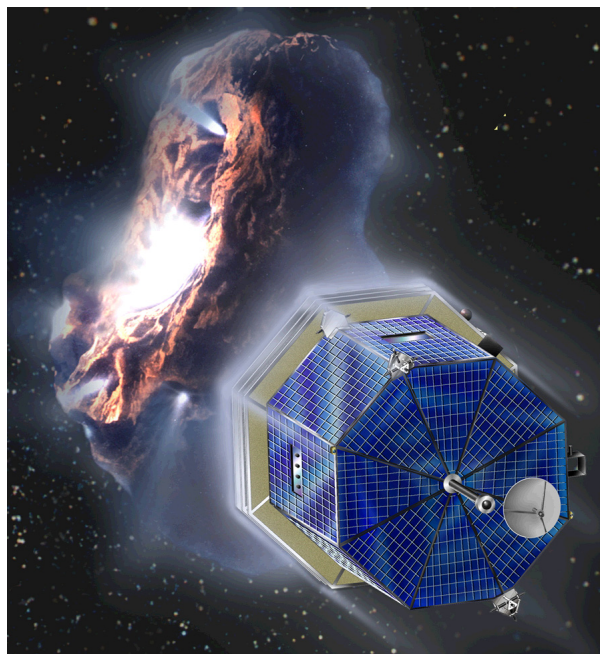
We led a GSFC team to develop unified onboard processing and spectrometry aimed at building compact, low-power, low-cost detectors to allow a wide field-of-view of the Earth with onboard processing, programmable by ground commands.

### ***Atmospheric Experiment Branch, Code 915***

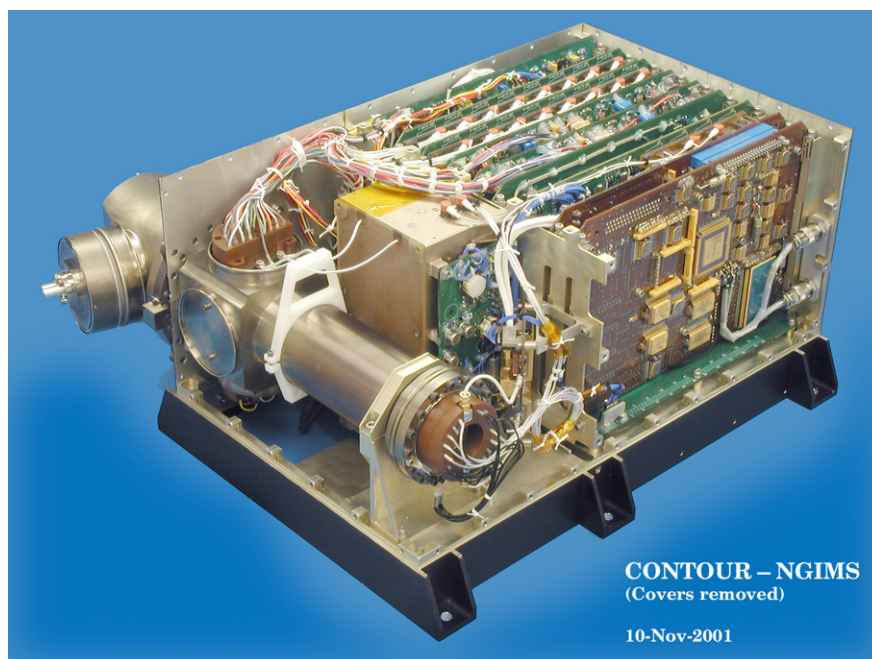
The Atmospheric Experiment Branch conducts experimental studies to increase our understanding of the chemical environment in our solar system during its formation and to study the physical processes that have continued to shape solar system bodies throughout time. To achieve this goal, the Branch has a comprehensive program of experimental research, developing instruments to make detailed measurements of the chemical composition of solar system bodies such as comets, planets, and planetary satellites that can be reached by space probes or satellites.

The Branch's accomplishments for 2001 include:

- 1) The Branch continued participation in the CONTOUR mission that will rendezvous with multiple comets and provide a more detailed understanding of cometary nuclei and the diversity among comets. CONTOUR is a mission in NASA's Discovery line of small mission programs for planetary studies. The CONTOUR PI is Professor Joseph Veverka of Cornell University. The Johns Hopkins University Applied Physics Laboratory (JHU/APL) in Laurel, Maryland, is managing the development of this spacecraft. The Neutral Gas and Ion Mass Spectrometer (NGIMS) is one of four instruments on this mission. CONTOUR was designed and fabricated in-house at GSFC with collaboration on the analog portion of the flight electronics by the Space Physics Research Laboratory (SPRL) of the University of Michigan. The instrument was delivered in late 2001 to JHU/APL for integration with the CONTOUR spacecraft. CONTOUR's launch is planned for July 2002. A significant activity for the NGIMS instrument team was the completion of the instrument calibration prior to delivery. The calibration was carried out for the numerous ions and neutral gases that are predicted to be present in the coma of comets. This was done using an array of solid, liquid, and gas sources for the ions and neutrals. Following this calibration, a series of environmental tests were carried out to establish the space worthiness of this hardware. The first comet encounter is planned for Encke on November 11, 2003.



**Figure 6-1. Artist's conception of CONTOUR spacecraft encountering a comet nucleus.**



**Figure 6-2. Neutral Gas and Ion Spectrometer instrument designed and fabricated in our Laboratory, one of four instruments on the CONTOUR spacecraft.**

2) The Branch continued providing post-launch support for several key planetary missions. These include:

A Gas Chromatograph Mass Spectrometer on the Cassini Huygens Probe mission to explore the atmosphere of Saturn's moon Titan.

An Ion and Neutral Mass Spectrometer on the Cassini Orbiter to explore the upper atmosphere of both Saturn and Titan.

A Neutral Mass Spectrometer on the Japanese *Nozomi* mission to explore the upper atmosphere of Mars.

3) We continue to refine flight data from the Galileo Probe Neutral Mass Spectrometer and to compare the chemical and isotopic compositions determined at Jupiter with those measured at Saturn and the other giant planets.

4) We continue advanced development for measurements on future missions. These include the following:

- A probe of the deep atmosphere of Venus to perform precision measurements of isotopes designed to resolve questions of the origin and processing of this atmosphere;

- A detailed in situ rendezvous mission with the nucleus of a comet to better understand the complexity of organic molecules that might have been delivered to Earth over the course of its history;

- A landed experiment on Mars to sample isotopes and molecules from its atmosphere and below its surface that can address studies of past climate and the possibility of past life on the planet.

5) We continued the collaborative effort with GSFC's Engineering Directorate in a comprehensive program to achieve a significant reduction in the size and weight of present-day mass spectrometer systems. This includes reduction in the electronics system by utilizing Application Specific Integrated Circuits (ASICs) and other advanced packaging techniques as well as reductions in the mass spectrometer itself by utilizing MEMS (Micro Electro Mechanical Systems) techniques.

#### ***Atmospheric Chemistry and Dynamics Branch, Code 916***

The Atmospheric Chemistry and Dynamics Branch conducts research in the distribution and variability of atmospheric ozone by making new measurements, by analyzing existing data, and by theoretically modeling the chemistry and transport of trace gases that control the behavior of ozone. An emerging research focus is the characterization of sources, sinks, and transport of aerosols, carbon dioxide, and ozone in the troposphere.

The Branch's accomplishments for 2001 include the following:

1) Several Branch scientists are playing key roles in the WMO/UNEP assessment of the stratospheric ozone depletion. This congressionally mandated assessment, held every 3 to 4 years, brings together experts in stratospheric research to assess the current health of the ozone layer and to make informed predictions about its future state. A key input to this assessment is the long-term global record of ozone created by combining ground-based and satellite data. Branch scientists continue to play a leading role in maintaining such a data set.

2) Several Branch scientists are members of the International OMI science team. OMI is a Netherlands-provided instrument, scheduled to fly on the EOS Aura satellite in 2003. This team recently completed a 4-volume description of the scientific algorithms that will be used to process OMI data to derive a variety of products relevant in atmospheric chemistry research. This document is currently undergoing peer review.

3) NASA Headquarters selected several Branch scientists to become members of the newly reconstituted TOMS science team. This included funding to continue the SHADOZ (Southern Hemisphere Additional Ozonesondes) program. This international program, managed by the

Branch, has greatly improved the quality and quantity of ozone vertical profile data in the region of the world that is experiencing rapid environmental change. These measurements have been extremely useful in validating satellite-derived estimates of tropospheric ozone.

4) The Branch started a major new initiative aimed at understanding the regional scale variability of carbon dioxide in the boundary layer. This includes the development of new modeling tools as well as new instruments to measure, with extremely high accuracy, column CO<sub>2</sub> and its vertical distribution in the boundary layer.

5) The Branch scientists developed a state-of-the-art capability to model global transport of desert dust. These models are not only helping in the interpretation of aerosol data derived from TOMS, SeaWiFS, and MODIS, but have also been used to plan field campaigns to study air quality in southeast Asia.

## Scientific Research Highlights

Now that you've seen general summaries of our Branch accomplishments, let's have a closer look at some of the results of our research. The following pages present the Laboratory's scientific highlights for 2001, divided into three disciplines: Measurements, Data Analysis, and Modeling. Table IV lists the contents of these three sections. The authors and topics were selected by the respective Branch Heads.

**Table IV: Summary of Scientific Research Highlights for 2001**

Measurements	Data Analysis	Modeling
<b><u>Ground-Based Measurements</u></b>	<b><u>Aerosol Studies</u></b>	<b><u>Data Assimilation</u></b>
<b>South Pole MP Lidar Experiment</b> James Spinhirne, Code 912	<b>Measuring Dust Absorption from MODIS and Landsat</b> Yoram Kaufman & Lorraine A. Remer, Code 913	<b>Impact of QuikSCAT Data on Numerical Weather Prediction</b> Robert Atlas, Code 910.3
<b>Micro Pulse Lidar Network</b> James Spinhirne, Code 912	<b>Climatic and Ecological Impacts of Asian Dusts</b> Si-Chee Tsay, Code 913	<b>Monitoring of Observation Errors Using the GEOS Ozone Assimilation System</b> Ivanka Stajner, Code 910.3
<b><u>Instrument Development</u></b>		
<b>Unified Onboard Processing and Spectrometry</b> Si-Chee Tsay, Code 913	<b>Modeling of Tropospheric Aerosols</b> Mian Chin, 916	<b>Assimilation of Cloud- and Land-Affected Satellite Sounding Data at the Data Assimilation Office</b> Joanna Joiner, Code 910.3
<b>GLAS Algorithm Development</b> James Spinhirne, Code 912	<b>Studies of Radiative Forcing of Saharan Dust Aerosols</b> Jay Herman, Code 916	<b>A Simple Framework for Assessing the Information Content of Observations from a Satellite Doppler Wind Lidar</b> Lars Peter Riishojgaard, Code 910.3
<b>ISIR/COVIR Project</b> James Spinhirne, Code 912	<b><u>Atmospheric Chemistry</u></b>	<b>Water Vapor Tracers as Diagnostics of the Regional Hydrologic Cycle</b> M. Bosilovich, Code 910.3
	<b>Extremely Cold Temperatures and the Absence of Polar Stratospheric Clouds during SOLVE</b> John Burris, Code 916	<b>Retrospective Data Assimilation</b> Ricardo Todling, Code 910.3
	<b>Measured Arctic Ozone Loss during the SOLVE Campaign</b> Thomas J. McGee, Code 916	<b>Can We Predict the Next Dust Bowl?</b> Siegfried Schubert, Code 910.3
	<b>Changes in the Earth's UV Reflectivity from the Surface, Clouds, and Aerosols</b> Jay Herman, Code 916	<b>High-Efficiency High-Resolution Global Model Development at the Data Assimilation Office</b> S.-J. Lin, Code 910.3
	<b>Global Mapping of Underwater UV Irradiances</b> Jay Herman, Code 916	<b>Improving Global Analysis and Forecasts Using TRMM and SSM/I Observations of Precipitation Processes</b> Arthur Hou, Code 910.3
	<b>Simulating Global Distributions of CO<sub>2</sub></b> Randy Kawa & Aryln Andrews, Code 916	

	<p><b><u>Clouds and Precipitation</u></b></p> <p><b>Retrieved Vertical Profiles of Latent Heat Release Using TRMM Rainfall Products</b> Wei-Kuo Tao, Code 912</p> <p><b>The Effects of Amazon Deforestation on Rainfall</b> Andrew J. Negri, Code 912</p> <p><b>Sampling of the Diurnal Cycle of Precipitation Using TRMM</b> Andrew J. Negri, Code 912</p> <p><b>On Rainfall Modification by Major Urban Areas: Observations from Spaceborne Rain Radar on TRMM</b> J. Marshall Shepherd, Code 912</p> <p><b>Cirrus Cloud Microphysical Modeling</b> R.-F. Lin, Code 912</p> <p><b><u>Climate Variability and Climate Change</u></b></p> <p><b>Hydrologic Teleconnections during Northern Summer</b> W. K. M. Lau, Code 913</p> <p><b>Cloud, SST, and Climate Sensitivity Inferred from Satellite Radiance Measurements</b> M.-D. Chou, Code 913</p> <p><b>Global Warming: Evidence from Satellite Observations</b> P. Cuddapah, Code 913</p>	<p><b><u>Hurricanes</u></b></p> <p><b>Simulation of the Cloud-Scale Structure of an Atlantic Hurricane</b> Scott Braun, Code 912</p> <p><b>Studies of Hurricanes During CAMEX-4</b> G.M Heymsfield, Code 912</p> <p><b><u>Physical Processes</u></b></p> <p><b>Global Solar Oscillations</b> Charles Wolff, Code 915</p>
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## Measurements

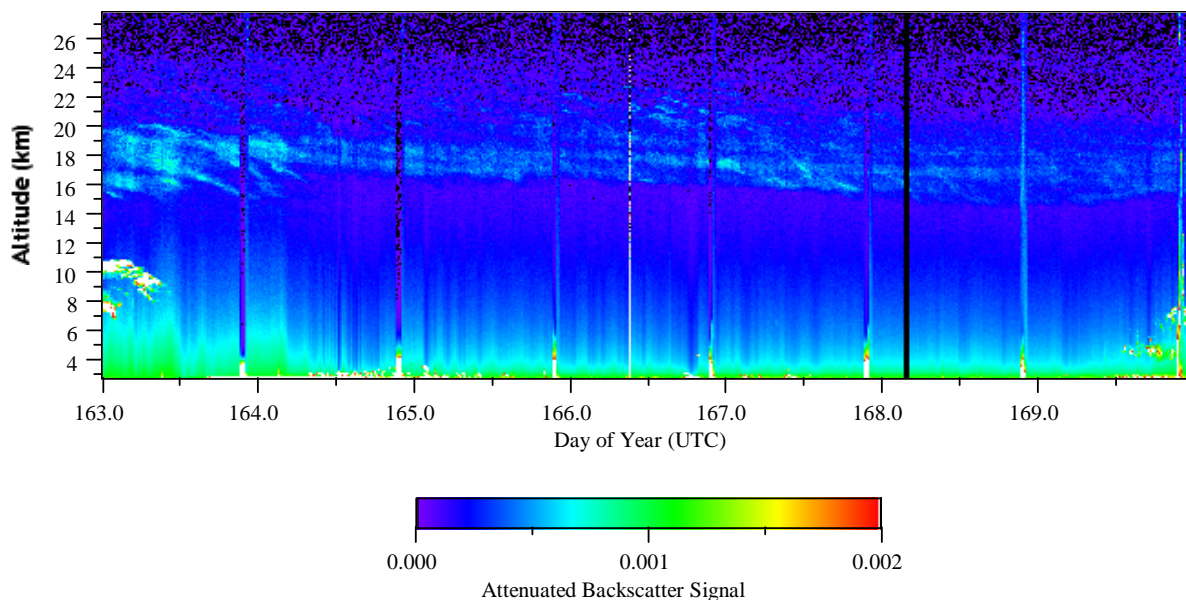
### Ground-Based Measurements

#### South Pole MP Lidar Experiment

The second full year of operations by the Micro Pulse Lidar at the U.S. South Pole Station was completed. We continue to acquire observational data on cloud structure, blowing snow layers, and detection and height of PSCs. The figure shows the detection of PSCs and other clouds during the winter season of 2000. The South Pole lidar measurements have been very important for modeling GLAS signals, algorithm performance, and accuracy.

An improved MP lidar experiment was installed at the South Pole in December. The new hardware will allow regular scanning through zenith angles to determine the effect of specular reflection from gravitationally aligned ice crystals on lidar signals. The effect must be understood for GLAS signal analysis.

An agreement was made with NOAA ERL for the MP lidar experiment to become one of the facility measurements at the NOAA Atmospheric Research Observatory at the South Pole Station.



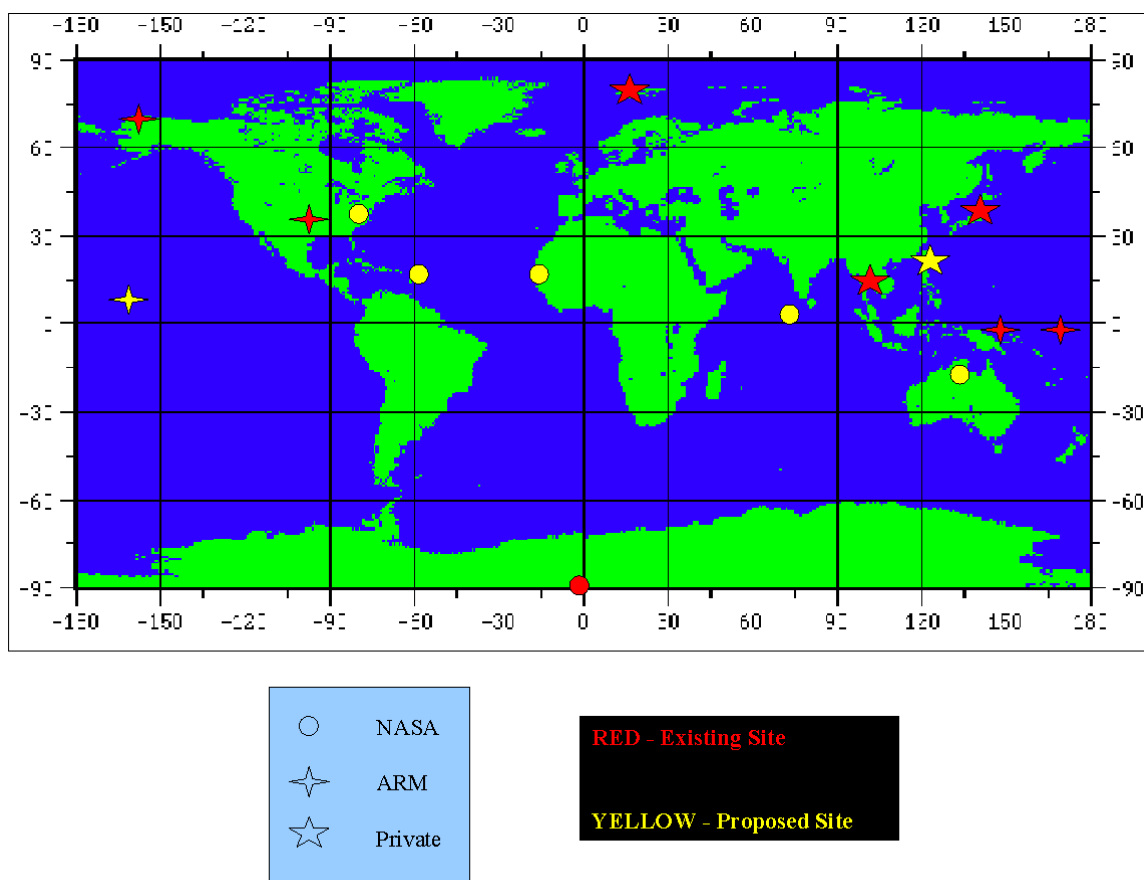
**Figure 6-3. South Pole MPL data for 1 week in June of 2000. The layer at 16 to 18 km is Polar Stratospheric Clouds. At the surface is a persistent layer of blowing snow.**

James Spinhirne, Code 912 ([James.D.Spinhirne.1@gsfc.nasa.gov](mailto:James.D.Spinhirne.1@gsfc.nasa.gov))

### Micro Pulse Lidar Network

The Micro Pulse Lidar was developed in the Laboratory as the first eye-safe, stand-alone lidar capable of full-time monitoring of atmospheric clouds and aerosol. The MPL-Net project became operational in 2001 with eight sites, four supported by the DOE ARM program and two by a Japanese partner. The figure shows the location of the sites. The MPL-Net Web site also came into operation with both low-level and some high-level data products now available to the outside community.

In addition to the permanent sites, three MPL-Net instruments successfully participated in the Aerosol Characterization Experiment–Asia (ACE–Asia) in the spring of 2001. In an unusual occurrence, the GSFC MPL site observed Asian dust transported over the Pacific and the U.S. The sites in Oklahoma and Alaska and the systems deployed for ACE–Asia have also detected the dust. The monitoring of aerosol transport is an example of the application of data from the network. MPL-Net data products are available to the community via the MPL-Net Web site (<http://virl.gsfc.nasa.gov/mpl-net/>).



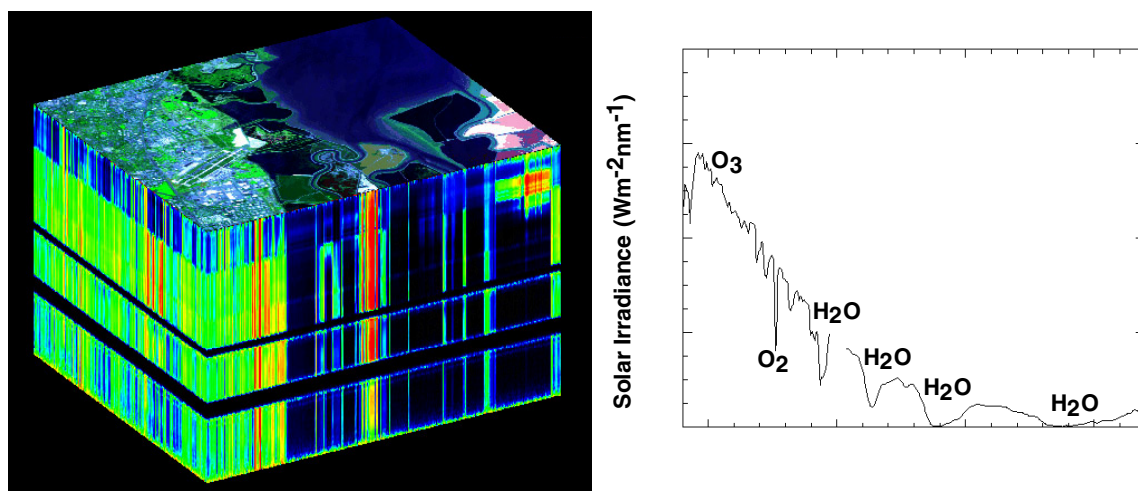
**Figure 6-4. A map of the locations of existing and proposed MPL sites.**

James Spinhirne, Code 912 ([James.D.Spinhirne.1@gsfc.nasa.gov](mailto:James.D.Spinhirne.1@gsfc.nasa.gov))

## Instrument Development

### Unified Onboard Processing and Spectrometry

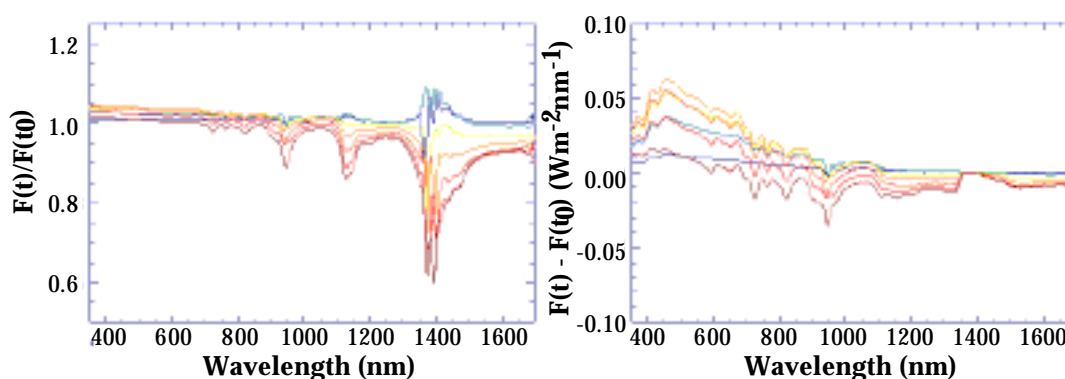
Leading remote-sensing scientists are increasingly convinced that spectrometers are the wave of the future in passive Earth remote sensing. Spectrometers are becoming cheaper, simpler, and more robust than classical filter radiometers, and, indeed, they may soon become generic off-the-shelf space instruments. Spectrometers can satisfy the needs of many communities that heretofore felt compelled to build new custom radiometers for every new mission, at huge costs. However, a difficulty arises from the vast volume of data generated by an imaging spectrometer sampling in the spatial and spectral dimensions. Figure 6.5 shows a typical image cube. The radiance field acquired by a spectrometer contains seven dimensions: spectral ( $\lambda$ ), spatial ( $x, y, z$ ), angular ( $\theta, \phi$ ), and temporal ( $t$ ). Nearby samples and/or sequential data are often highly correlated. For example, at a given time and position, the spectral data (*cf.* Figure 6-5) generally reveal a high degree of correlation between closely spaced spectral bands. We urgently need to learn how to compress the data in an intelligent way that retains the information.



**Figure 6-5. An image cube (left panel), horizontal for spatial and vertical for spectral data, acquired by the Airborne Visible/Infrared Imaging Spectrometer, which is a NASA facility instrument based at JPL. Downwelling solar irradiance spectra (right panel), collected by the Solar Spectral Flux Radiometer at NASA Ames Research Center, depict several absorption features by atmospheric gases.**

With the surge of advanced spectrometry, sensor data accumulate at a rate and abundance that not only necessitates efficient data compression and storage but also imposes critical demands on the communication downlink and the ground data-management system. A typical hyperspectral spectrometer produces about 170 MB of data per second, or a total volume of 1 TB in one 94-min orbit. (This example assumes a spectrometer of 200 wavelengths on a  $1\text{K} \times 1\text{K}$  detector array, imaging the Earth every 100 km—or every 14 sec at 800 km altitude—with a 12-bit data system.) This rate of data capture requires 1.6 GB/sec downlink bandwidth for a 10-min communication window per orbit, or 10 times our current X-band capacity. Thus, with this new generation of instruments, the “archive all the raw bits” paradigm has reached the end of its utility. Keeping this paradigm would require either an EOSDIS 10 times bigger than the present one (i.e., something NASA simply cannot afford) or draconian restrictions on the amount of data taken by the instruments. Onboard data compression provides a viable alternative to both of these unpalatable choices.

A group of scientists (GSFC and Ames) and engineers (GSFC and JPL) is interested in this largely unexplored territory. We contend that spectrometry and its onboard processing algorithms must advance in unison and eventually unite seamlessly. This is a potentially revolutionary instrument concept with considerable spin-offs for many space missions. We envision a future in which archives of the spectrometer output will not be a monstrous data-dump of spectra, but rather the *information content* of those spectra, undoubtedly a much smaller and more valuable data stream. We propose to take full advantage of existing spectral observations to develop and refine two compression algorithms, named *proximate differencing* and *physics-based removal* techniques. Both are *reversible* (i.e., the information removed can be restored on the ground, as needed). The information removed from a measured spectrum can be of two types: (1) that which is known a priori, whether from theory or from measurements done off-line (e.g., extraterrestrial solar spectrum, known absorption/scattering spectra, etc.) and (2) that which is measured by the spectrometer itself, proximate in either space or time. Clearly an optimal combination of these two strategies needs to be sought. An example of method (2) is presented in Figure 6-6, which shows how spectra can be flattened (thus made more compressible) by dividing or subtracting out spectra contiguous in time.



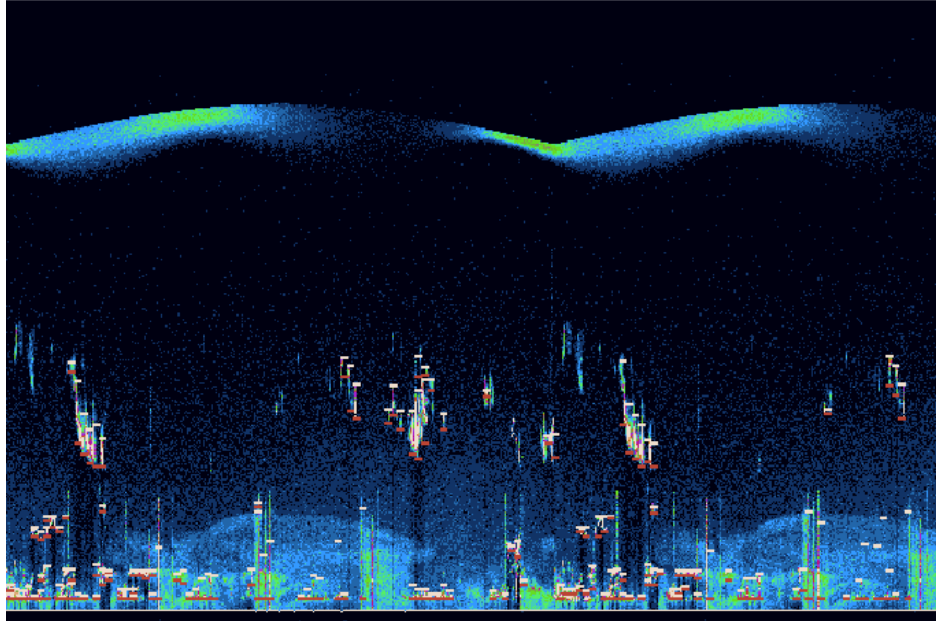
**Figure 6-6.** Used for illustration are six spectra of upwelling flux, similar to that shown in Figure 6-5, collected from above a stratus cloud deck over a 5-minute period during a recent field deployment. The left panel shows ratios and the right panel differences of each of the six spectra to one collected just prior to the start of this 5-minute period. Clearly the ratio method is useful except for the blowup that occurs in the nearly saturated water vapor absorption in the 1.4- $\mu\text{m}$  region.

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#### GLAS Algorithm Development

The launch of the Geoscience Laser Altimeter System (GLAS) aboard the Ice, Cloud, and Land Elevation Satellite (ICESat) in 2002 will mark the advent of global space-based laser profiling of the atmosphere and the planetary surface. For atmospheric science, GLAS cloud and aerosol measurements address critical applications not available from existing satellite observations. ICESat's unique lidar observations include the direct measurement of cloud heights, monitoring of aerosol distributions, and all-year coverage of clouds and aerosols in polar regions. Our lidar group is developing the launch algorithms for the Geoscience Laser Altimeter System (GLAS) atmospheric data products. The preliminary algorithms were delivered to the Science Computing Facility group for GLAS, and initial testing has been successful.

GLAS measurements will provide a global data set for direct detection of atmospheric cloud and aerosol layers with a high accuracy that has not been previously available. Detection is possible because atmospheric regions containing cloud or aerosol constituents have greater volume backscatter coefficients than clear regions. One of the data product algorithms analyses signals by filtering noise to delineate particle layers within the lidar profile. The figure below shows a simulation of GLAS data for a partial orbit with aerosol and cloud layers present. The algorithm successfully discriminates between cloud and aerosol layers.

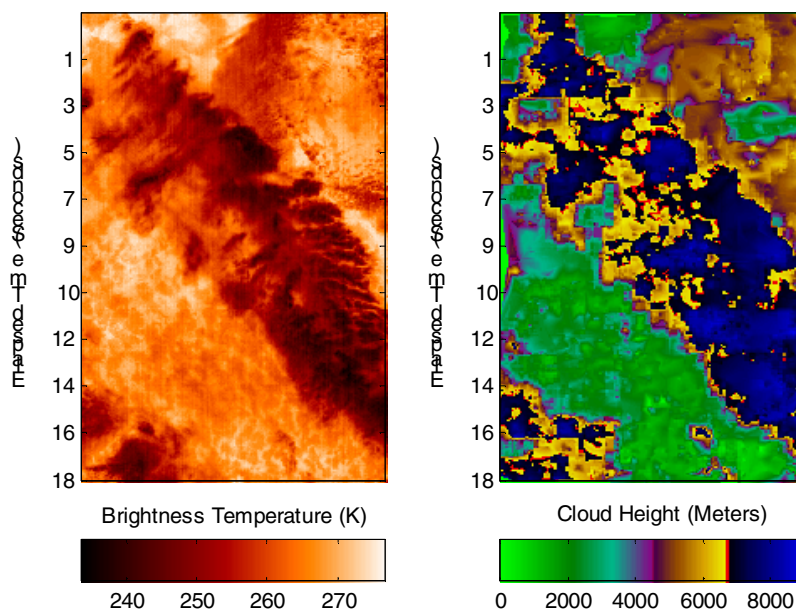


**Figure 6-7. GLAS signal simulation showing algorithm retrievals of cloud heights. The white and red lines indicate clouds detected. Layers not detected are aerosol. The ability of the algorithm to discriminate between cloud and aerosol signals is demonstrated.**

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#### ISIR/COVIR Project

The Infrared Spectral Imaging Radiometer (ISIR) instrument was flown in space as a shuttle hitchhiker experiment. The goal of the experiment was to test a new type of infrared cloud sensor. The enabling new technology consisted of uncooled, microbolometer infrared array detectors. One advantage of the uncooled array detector was to enable imaging radiometers of smaller size and lower cost. Another advantage was that an imager could be made that would provide directionality of radiance in addition to spectral information. Since the shuttle experiment, ISIR data has been analyzed to test the application of the spatial information in data. Analysis was completed and a paper submitted on the results of infrared stereo cloud height retrieval. Figure 6-8 shows an example of stereo height retrieval.



**Figure 6-8.** The panel on the left shows a sample of the imagery obtained using the ISIR instrument during mission STS-85. These data have been calibrated into units of brightness temperature, as measured through the 10.2  $\mu\text{m}$  channel of the instrument. The panel on the right shows the corresponding estimates of cloud height obtained stereoscopically. Here, a multilayered cloud system is seen that includes an aged contrail at an altitude near 8 km.

The Compact Visible and Infrared Radiometer (COVIR), supported by the IIP program, is a follow-on to the ISIR instrument. COVIR is intended as an engineering model of an operational satellite imager. Completion and testing of the instrument is awaiting delivery of the spectral filter arrays in 2002.

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